Charles Robb,
Civil, Mechanical & Mining
ENGINEER.
PATENT SOLICITOR.
[illegible] St. Room 15,
MONTREAL.

PERSONAL.—The Halifax 'Mining Gazette' says that the many warm friends in the Province of Nova Scotia of Professor Robb, of Montreal, will be pleased to learn that that gentleman has been officially designated by Sir William Logan to superintend the geological survey of the Province of New Brunswick. Sir William himself will probably debark at Halifax on his return from Europe, and here institute steps for the Nova Scotia Survey.

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OBSERVATIONS ON THE PHYSICAL GEOLOGY OF THE WESTERN DISTRICTS OF CANADA.

BY CHARLES ROBB, C.E., HAMILTON, C.W.

From the Canadian Journal for November, 1860.

The investigation and illustration of the geological structure of the surrounding country, whether we regard it simply as a matter of scientific interest or of practical utility, must ever form one of the most prominent objects of such Associations as that of which this *Journal* is the organ. To those whose previous studies have given them a taste for, and aptitude in, such pursuits, no subject can possess greater interest, or add greater zest to the enjoyment of their excursions, whether of business or pleasure; while even to those whose acquaintance with geological science may be but superficial, the knowledge of those causes which have operated in determining the configuration of our coasts, and in producing the most prominent features of the scenery by which we are surrounded, must be a source of pure and elevating enjoyment. Again, as a striking instance of the benefit of such investigations in a utilitarian sense, I need only advert to the fact that both in Canada and in the neighbouring State of New York, before the deductions of geological science were brought to bear upon the public mind, large sums of money were squandered in abortive attempts to find coal in rocks below the carboniferous series. In exposing the absurdity of such attempts, and thereby rendering the resources thus wasted available in more profitable channels, the science of geology has conferred on this Province a service which will amply justify the expenditure of the sums granted by Government for the prosecution of these researches.

Sir Roderick Murchison computes that the money expended in England alone, before geology was understood, in searching for coal where it would now be considered madness to expect it, would be sufficient to effect a correct general geological examination of the entire crust of the globe.

I propose, in this and subsequent papers, to lay before the readers of the *Canadian Journal* the results of such investigations into the physical geography of the western districts of Canada as I have had it in my power to make during a residence of upwards of eight years

in those parts of the Province. The region embraced in these explorations is that lying between the Niagara and St. Clair Rivers, and the object in view in undertaking and prosecuting them was chiefly the gratification of my own tastes, for which, however, professional engagements have afforded both opportunities and further stimulus. I lay but little claim to the merit of originality in the observations I shall have to record; the geological structure of the regions in question having been fully investigated and most ably reported on by our Provincial Geologists; and in stating my own observations I shall endeavour, as far as the nature of the subject will admit, to avoid repetition of the facts and phenomena which have been so fully chronicled by them, and to confine myself to such supplementary details and to such deductions and inferences as my own enquiries and studies may enable me to make. As illustrative of some of the most interesting peculiarities of structure in the region under notice, I propose also to reproduce the arguments of Sir Charles Lyell and other observers relative to the retrocession of the Falls of Niagara; in corroboration of which I have noted some additional facts which have not hitherto been recorded.

Section I.

GEOLOGICAL FEATURES OF THE NIAGARA AND GORE DISTRICTS.

General Description.—The range of high lands which we are accustomed to denominate "the Mountain" running eastwards far into New York State—maintaining throughout a nearly uniform elevation of about four hundred feet above the level of Lake Ontario, and forming a platform or table land, in a basin of which Lake Erie is situated—bends round the head of Lake Ontario and continues in a north-easterly direction till it gradually disappears in the neighbourhood of the Bay of Quinté. The same geological formations do not, however, occur throughout the whole of this distance, as I shall hereafter point out. Along the southern shore of the lake, the ridge runs at a distance varying from four to eight miles from the shore, and presents a nearly uniform precipitous escarpment on its northern flank. Around Burlington Bay it approaches still nearer the margin of the lake, and at East Flamboro' bends to the northward and loses for the most part its precipitous character, and recedes gradually further from the shore, being not less than twenty-four miles distant in the rear of Toronto, though again, as we

proceed farther east, we find it approach within nine miles. With the exception of the Niagara River, no streams of any importance empty themselves into Lake Ontario throughout this region, as might naturally be expected from the proximity of the ridge to the shore; and that remarkable river itself, as I shall hereafter show, presents anomalies and peculiarities perhaps nowhere else to be met with in nature.

The geological structure of this region is remarkably simple, exhibiting no faults or distortions of the strata; but it is far from being less interesting either to the geologist or the general observer on that account. The rocks immediately underlying the superficial deposits consist of various members of the Silurian or oldest fossiliferous strata. They belong to those divisions of the Silurian system called the Middle and Upper Silurian, corresponding to, and no doubt contemporaneous with, the Carradoc, Ludlow and Wenlock groups of England. Nowhere do we find a more interesting region in a geological point of view. Referring to it, or rather to the continuation of the same formations in New York State, Sir Charles Lyell remarks:—"If we wish to see in perfection the oldest monuments of the earth's history, so far at least as relates to its earliest inhabitants, we must look here. Certainly in no other country are these ancient strata developed on a grander scale, or more plentifully charged with fossils; and as they are nearly horizontal, the order of their relative position is always clear and unequivocal. They exhibit, moreover, in their range from the Hudson River to the Niagara, some fine examples of the gradual manner in which certain sets of strata thin out when traced to great distances, while others become intercalated in the series. Thus, for example, some of the limestones which are several hundred feet thick in the Helderberg Hills, near Albany, are scarcely forty feet thick in the Niagara district; and, on the other hand, the rocks over which the cataract of Niagara is precipitated, dwindle away to such insignificant dimensions when followed eastward to the hills south-west of Albany that their place in the series can scarcely be recognized." Sir Charles adds "that a comparison of the fossil remains found in those ancient strata with those of a corresponding age and position on the other side of the Atlantic, shows that while some of the species are identical the majority are not, and that however close the general analogy of the forms may be, there is evidence of the same law of varieties in space

as now prevails in the living creation." Since Sir Charles wrote the above remarks it has been ascertained on a more minute investigation that the number of species common to the Silurian rocks on both sides of the Atlantic is between thirty and forty per cent.; and it is a most interesting fact that those which are identical are precisely those which are found most widely diffused both geographically and in the order of superposition, and consequently seem to have been most capable of surviving many successive changes in the earth's surface.

Professor Sedgwick, at the recent meeting of the British Association in Aberdeen, in speaking of this order of geological formations, characterized them by a figure quaint and graphic, though derived from modern feminine usages. He speaks of the limestone formations as a great girdle, or (in plain terms,) "hoop," over which Dame Nature had spread her "glorious palæozoic petticoat." Certainly nowhere on the face of the globe has this skirt attained a greater expansion, or been more gorgeously bedecked with the forms of ancient life, than in the locality now under notice.

Details of the Rock Formations.—A very complete and most interesting section of the strata in a line running north and south, is afforded by the cutting on the line of the Niagara Falls and Lewiston Railroad, and by the ravine itself through which the great river flows.* Taking the section at this most interesting locality as the basis of our future enquiries, I shall proceed to describe briefly the component parts, and shall take occasion while it is under review to recapitulate the arguments of Lyell and others, to prove the fact of the retrocession of the Falls from Queenston Heights to their present site.

The strata in ascending order consist, first, of a soft red shaley and purely argillaceous marl, partially striped and spotted with green, seen in the bank of the river at Queenston and extending thence to Lake Ontario, and attaining a height of about one hundred and ten feet at the escarpment at Queenston. This formation, which is entirely devoid of calcareous matter, is regularly stratified, and interspersed with thin veins of a light green rock of similar composition though somewhat harder, the colors being evidently derived from the presence of iron. The traces of organic remains in this bed are

* This section is represented graphically in Sir Charles Lyell's *First Visit to the United States*, 1841-2, Vol. I. page 36, to which we would refer our readers.

very obscure though not altogether wanting, and it is chiefly remarkable as forming the base of the system, and as occupying the entire area between the foot of the slope of the mountain and the lake shore for the whole distance from the Niagara River to Oakville.

The second stratum is a bed of very hard light grey quartzose sandstone, marked frequently with ferruginous spots, but forming an excellent building material, and quarried extensively at Lewiston, Hamilton, Dundas and other places. This bed is about fifteen feet thick at Queenston, and contains the remains of fuci or sea weeds. I have also observed it to be distinctly ripple-marked in some localities. Above this for a thickness of about sixty feet occur alternate layers of red shale or marl, similar to No. 1, and of sandstone or limestone, the former principally near the top of the formation. The harder rocks here are particularly rich in organic remains, some in a beautiful state of preservation, and all remarkably characteristic of the geological epoch to which these formations belong, consisting of corals, brachiopods of various species, tentaculites, encrinites and trilobites. Of the trilobites, a remarkable crustacean genus strikingly characteristic of the Silurian system all over the world, I have only detected a few fragments, but they are sufficiently unequivocal.

Next in succession is a grey and mottled sandstone about fifteen feet thick, forming the upper member of what is called by the New York State Geologists the Medina Sandstone group. Encrinites, corals and broken shells prevail in great abundance at the top. Overlying this bed is a band of light green shale five feet thick, turning into clay on exposure to the atmosphere. This stratum forms the lower member of the Clinton group of New York, and is remarkable as being traceable for vast distances east and west in precisely the same relative position, and of identical mineral character. Next in order occurs a compact bed of light grey, very hard limestone, about sixteen feet in thickness, copiously charged throughout its entire mass, but chiefly towards the top with the bivalve shell *Pentamerus* (a genus also found extensively in a corresponding position in the Silurian systems of England and Russia) as also with a few species of *Atrypa*, a remarkable coral called *Favosites gothlandicus*, &c. This bed forms the upper member of the Clinton group, and wherever it is found is an exceedingly handsome and durable stone for building purposes. Owing to its hardness it forms a distinct escarpment wherever exposed for any length of time to the weather. Then

follows the formation usually denominated Niagara shale, about eighty feet thick, consisting of a homogeneous stratified or laminated mass of bluish-grey, sometimes nearly black, argillaceous, arenaceous and calcareous slatey rock, hard and solid in the bed, but decomposing and crumbling when exposed to the atmospheric influences. It seems to be devoid of fossils, except towards its junction with the underlying hard limestone, where it is plentifully charged with *Pentamerus* and *Atrypa*.

Lastly. the escarpment is capped by the Niagara limestone, (so called) a massive and very hard dark blue or more nearly black rock, the lower portions being in very thick solid beds, while towards the top the partings occur more frequently. This rock is magnesian and silicious in mineral character, and is highly bituminous, being known in many places to emit inflammable gas through the seams. Occasionally it is cavernous in structure, and is copiously interspersed with druses or cavities containing calc-spar, gypsum and sulphate of Strontian. I have been uunable to detect any fossil remains in this formation, although I believe they are not altogether wanting. It is over this rock that the great cataract is precipitated, and it forms from its hardness a species of coat of mail or armour of proof to resist the too rapid erosions of the torrent.

Proofs of Retrocession.—It will serve at once to illustrate strikingly what may be called the mechanical properties of the strata we have been considering, and at the same time to show by a most remarkable example the value of geological evidence in regard to duration of time, if we take up at this stage the subject of the recession of the great Falls.

It has long been a well known fact, that behind the mighty cataract there existed a vast cavern formed by the action of the water and air set in violent motion by the descending torrent upon the soft shales underlying the Niagara limestones; and this fact must have suggested to an enquiring mind the idea, that as the soft material became gradually undermined or excavated, the weight of the superstructure and impetus of the water must have caused the harder superincumbent rock from time to time to give way, and thus occasion a recession of the Fall in its position. In accordance with this idea, it is found from historic evidence, (which unfortunately in this point affords less corroboration to geological theories than in questions relating to the old world), that changes of the kind referred to had

actually taken place; and the appearance of the bank below the Falls where these changes had occurred within the memory of man is so precisely identical in character with the whole gorge for seven miles below, that a philosophical observer of the phenomena of nature would be irresistibly impelled to the conclusion that the great Fall formerly existed at Queenston, and that the river must have sawed its way through this whole distance—provided sufficient time were allowed for the completion of the work. Sir Charles Lyell concludes, after the most careful and repeated investigation of the recorded facts, as well as the varying nature of the strata, that the average recession was not more than one foot per year, and that consequently it must have taken 35,000 years for the retreat of the Falls from the escarpment at Queenston to the present site. It seems by no means improbable that such result would be no exaggeration of the truth, although we cannot assume that the retrograde movement has been uniform. At some points, owing to the greater softness of the strata and the lesser width of the ravine, it might be expected that quicker progress might be made; but on the other hand, it must be observed that at the commencement of the process the Fall must have been nearly twice its present height and consequently the amount of material to be excavated proportionally greater. This estimate of the time required for the scooping out of the gorge, as Hugh Miller remarks, is based upon exactly the same process of reasoning by which one would infer that a labourer who had cut a ditch two hundred yards long at the rate of ten yards per day and was still at work without intermission, had begun to cut it just twenty days previous.

This theory based upon historical, is amply corroborated by geological evidence. If we examine the structure of Goat Island, between the American and Horse Shoe Fall, we shall find that the superficial deposit consists of regularly stratified horizontal fresh water beds of gravel, sand and loam, in all about twenty feet thick, copiously charged with shells of the same species as now inhabit the waters of Lake Ontario and the Niagara river. These beds are entirely above the level of the water as it precipitates itself into the mighty gulf. Precisely the same formation will be found on the American side of the river exactly opposite, and extending for a considerable distance below the Falls on the top of the cliffs, and bounded towards the east by a distinctly traceable ancient river

terrace cut out in the clay or drift formation which covers the whole country. This deposit, in which also the remains of a Mastodon have been found, occupies the place which the ancient bed, and alluvial plain of the Niagara would naturally have filled, if the river had extended farther northwards at a level sufficiently high to cover the greater part of Goat Island. At that period the ravine could not have existed, and the river must have been dammed back several miles lower down. The old river banks are distinctly traceable facing each other on both sides or the gorge, at least as far down as the Whirlpool, and vary in width from about thirty to three hundred feet from the brink of the precipice. At the summit of the cliffs overhanging the Whirlpool on the American side, there occurs a deposit forty feet thick of fluviatile strata, precisely identical with those on Goat Island; and it must be borne in mind that nowhere do these deposits extend, or can they be traced, beyond the old river banks.

Here then we have the most unequivocal evidence that at a date comparatively modern in the geological epochs, though very remote as regards the history of our race, the great Falls must have been situated at least four miles below their present site; and in the absence of distinct traces of their existence still further northward we may reasonably and justly infer that they must have primarily been situated at the escarpment at Queenston. There is no ground for supposing that the excavation was assisted by an original rent in the rocks, and no appearance of a fissure occurs at the present site of the Falls.

The dip of the strata being twenty-five feet to the mile southward, and the slope of the river bed about fifteen feet in a mile northwards, these two inclinations combined have occasioned a diminution of forty feet in the perpendicular height of the Falls for every mile that they have receded southwards. When they were situated at the Whirlpool, the hard quartzose sandstone was at the base of the precipice, and here the cataract may have remained stationary for ages. Even now the obstruction occasioned by this ledge in the bottom of the river causes a partial damming back of the water, which, overleaping this barrier, rushes with still more fearful velocity down the gorge. This phenomenon, together with a remarkable break (which I shall afterwards advert to) in the continuity of the strata on the Canadian side at this point have no doubt given rise to the Whirlpool. In regard to the future retrocession of the Falls it is susceptible of clear proof that when they have travelled back two miles or opposite to the

village of Chippewa, the massive Niagara limestone now at the top will then extend also to the base of the Falls, and its great hardness will probably arrest the excavating process, if it should not have been previously stopped by the descent of larger masses of the same rock from the cliffs above. In this latter case, instead of a fall we shall have a rapid of about the same slope as the present rapids above the falls, (fifty feet in three-fourths of a mile); but very much more broken and irregular owing to the greater size of the masses of rock forming the bottom.

The next question to which we are naturally led, relates to the origin of the Falls, but this subject I shall defer till the close of this article, when, after describing the principal geological features of the region bordering on the head of Lake Ontario, I shall attempt to indicate the succession of events which have produced them.

Strata traced Westwards.—The various members of the series of rocks already described, are also exposed in tracing the escarpment running parallel to the shores of the lake, from Niagara to Flamboro'. The strata lie nearly horizontally from east to west, but dipping slightly to the eastward, the dip of the lower standstone bed (called by the quarrymen the Gray band,) which rests immediately on the red marl, being at the rate of twenty-two inches per mile. An attentive observation of the section thus exposed will shew the remarkable manner in which certain of the beds thin out and die away as you follow them westwards; while others not to be discovered at the Niagara river are intercalated in the series, and as they are traced in a northwest direction attain to a great thickness, still retaining their distinctive characters. Thus the great deposit of dark shale, which at the Falls shews a thickness of eighty or ninety feet, is represented at Flamboro' by a bed of only five feet thick; while the encrinal and cherty limestone, which at Flamboro' occupy a most prominent place in the group, die out gradually and are scarcely to be detected at the Falls.* This same encrinal limestone, which at Flamboro' is only

* This phenomenon, which is not peculiar to the Silurian or to any other system, though nowhere perhaps more strikingly apparent than in this locality, may, I conceive, be accounted for in three ways: Either, 1st. That in the wide and deep ocean in which these deposits were made, certain of them never reached the deeper portions, but subsided along its shores; Or, 2nd. It may have been caused by certain portions being too shallow or even upraised above the surface of the water. Or, 3rdly. After the deposition of the stratum, it may have been uplifted so near to the surface of the sea, as to have been worn away by the waves, and thus have allowed a succeeding deposit to come directly upon one of preceding date.

about twenty feet thick, is observed to attain a thickness of one hundred feet in Eramosa, Nassagaweya and Caledon. This limestone, as well as the underlying Clinton limestone, is everywhere well adapted to form an excellent and durable building material, and is likewise of good quality for burning into lime. It forms wherever it crops out a bold escarpment (which may be called the Niagara ridge) owing to its solid and apparently unstratified character. This escarpment is distinctly traced from West Flamboro' eastward into Nelson, where it takes a sweeping turn to the north, and maintains a nearly straight course in that direction until it reaches Owen Sound near Sydenham village. The dark bituminous limestone which forms the upper member of the group follows the same course, which, however, is not so distinctly marked, owing to its being stratified in thinner beds, and occupies throughout from the Niagara River to Owen Sound, a breadth of country varying from eighteen to twenty or twenty-two miles.

The red marl which forms the base of our series of rocks is supposed to be about 614 feet thick. The bore which yields the mineral water at St. Catherines pierces it for a depth of nearly four hundred and seventy feet without passing through it, and the level at which the bore commences is one hundred feet below its upper surface. It seems geographically to come to an abrupt termination at the west bank of the Creek at Oakville, and is there succeeded by the Lorraine Shales, or Hudson River Group—an older formation consisting of alternate very thin beds of limestone and shale, which extend from this point along the north side of Lake Ontario to the River Rouge in the township of Pickering, immediately adjoining Scarboro'. A good section of this formation is exposed on the east bank of the Don at Toronto. A bore which was executed under my directions at the Toronto Station of the Great Western Railway, penetrated it for a depth of one hundred and fifty feet without change. The water which this bore yielded was salt and bitter, and a considerable quantity of carburetted hydrogen gas was evolved.

I may here remark in passing that in the spring of 1855 a great land-slide occurred on the slope of the mountain a little below Dundas Station, which displaced a portion of the track of the Great Western Railway, and was caused by the weight of the debris of the harder rocks above sliding along the face of the soft shales which, by exposure to the weather, resolve themselves into an unctuous sort of clay.

I may also notice that in filling up the old channel of the Desjardins

canal, enormous quantities of material were thrown in and disappeared, producing no effect in forming a bank, but forcing up the soft material in the original bottom of the marsh, to a considerable extent and height above the surface. This affords a good illustration on a small scale, of what the geologist often finds on a large scale, and may be puzzled to account for; I refer to the displacement of strata, formed in horizontal position and thrown up into a highly inclined or even vertical position.

Waterlime and Ochre.—Before noticing the superficial deposits of this region, I shall direct attention briefly to the waterlime and ochre beds of Thorold, which are somewhat extensively worked for commercial purposes, and occur about three hundred feet above the level of the Lake, and close on the line of the Welland Canal at Thorold. The waterlime deposit consists of a series of thin layers (each layer not exceeding eight to ten inches thick) in all about three and a half to four feet thick, of very hard compact dark blue limestone, corresponding in position and probably identical with the Clinton group. These beds are in some places a perfect congeries of large bivalves, called *Pentamerus oblongus*, some of them measuring three and a half to four inches across, while the partings of the beds are beautiully marked with fucoids of various species. The limestone from this bed, when calcined and ground to powder, forms an hydraulic cement of the best quality; owing this peculiar property to the presence of a large proportion (over ten per cent.) of silica or silicates. Immediately underlying and overlying this bed, are thin layers of a softer stone, which, when calcined and ground, forms an excellent drab coloured pigment; a rich brown paint, said to be fireproof, is also manufactured at Thorold, from material found in the same quarries. Whether these peculiar products extend far to the east or west of the localities where they are at present quarried, I am unable to say; but at Rochester there occurs an iron ore bed at the same place in the series, and Dr. Mack of St. Catherines has ascertained that the stone from the drab ochre bed contains forty per cent. of iron.

Superficial Deposits.—I shall now, as briefly as the subject will admit, direct your attention to the superficial deposits of this region, and the proofs of glacial action which they afford. It is now pretty generally conceded, and in fact cannot on any reasonable ground be denied, that the thick deposit of clay, sand, gravel and boulders which covers the Western districts of Canada, (in many places upwards of

one hundred feet beneath the general surface, and along the shores of Lake Erie and elsewhere forming hills one hundred and fifty feet above the general level,) is due to what is called by geologists the glacial period, and the phenomena referable to this epoch, are precisely similar on both sides of the Atlantic. From well known cosmical laws, ice-bergs and fields of floating ice are constantly, in seas north of the fortieth parallel of latitude, passing from the Polar regions in a direction from N.E. to S.W. and are conveyed for hundreds of miles from their original birth-places; and these are frequently found to be charged with vast quantities of mud, sand and boulders, the debris of the granitic rocks which mostly occupy these regions. These ice-islands become stranded in seas too shallow to float them, and as the ice is melted, deposit their insoluble contents at random over the bottom of such seas, and the deposits thus formed would be stratified or unstratified according as the water was in a quiescent state or disturbed by currents. The slow passage of these ponderous masses, armed with such refractory materials, over the rocks forming the bottom of the seas, would grind down their upper surfaces, removing great quantities of their constituent materials, and producing grooves, furrows and scratches in the normal direction of their course. We have, on a small scale, an example near our own doors of the effect of ice in removing masses of rock. I refer to the fact that the isolated rock called Gull Island, between Cobourg and Port Hope, two miles from the northern shore of the lake, and on which the lighthouse is built, formed at the time of the early settlement of the country, an island of over two acres in extent, but is now only a sunken reef, owing doubtless to its having been as it were decapitated by the ice forming over and adhering firmly to its upper beds, which would be borne away with the floating ice during storms. The same process is continually going on upon a larger scale in Lake Superior, and the observations of navigators in the Arctic regions supply, on a still more extensive scale, all the "modern instances" requisite for the corroboration of the theory.

Now it is an interesting and important fact that the constituent materials of the clay, sand and gravel which cover the greater part of Canada West, are derived from granitic and trappean rocks; that the boulders embedded in the clay and strewed over the surface are, for the most part, fragments of the same rocks; that these rocks are found in their native beds invariably in a North-easterly direction, and that

the surfaces of the harder rocks *in situ* in the peninsula, wherever exposed by the removal of the drift, are found to be smoothed, polished, furrowed and scratched in a direction from N.E. to S.W. Any one who has had occasion to visit Niagara Falls will see this phenomena strikingly developed along the top of the cliff on the American side, and at the excavation for the Hydraulic canal, about half a mile below the Fall. That this smoothing and scratching of the rocks could not be produced simply by the action of torrents of water carrying stones with it, may be satisfactorily proved by examining the rocks in the bed of the river, which, even where the current is most rapid, exhibit no analogous effect.

General Inferences.—In order to account for all the phenomena I have thus briefly sketched, we are irresistibly impelled to the conclusion that subsequently to this region having acquired its present geographical configuration, so far as relates to the outline of the older rocks, the land was submerged under the sea to a moderate depth, and that large ice-islands were driven by currents from the north, charged with mud, sand and boulders, which, as they grounded on the bottom, pushed along all loose materials of sand and pebbles, broke off all angular and projecting points of rock, and when fragments of hard stone were frozen into their lower surfaces, scooped out furrows and grooves in the subjacent rocks. When the icebergs melted, the soft and loose insoluble materials which they conveyed subsided into the bottom, filling up valleys in the ancient rocks, covering them under a mass of clay and sand where currents were powerful enough to reduce the deposits to a general level, and forming mounds and hillocks of the same, in places where such currents did not prevail. That this was actually the case is proved by independent evidence, namely, the occurrence of marine shells of recent species, in the drift formation at various heights above the level of the sea in the region drained by the St. Lawrence.

Burlington Beach and Heights.—Of this nature and origin I have no doubt are the remarkable formations of the Burlington Beach and Heights, which seem to have been expressly designed by Providence, the first as a natural rampart and breakwater to protect our magnificent harbour, and the latter as a bridge to facilitate our communications by land. The immense masses of clay and drift which conceal the older formations between Dundas and Copetown render it impossible to say with certainity whether the latter preserve the same precipitous

and continuous character round the head of Burlington Bay as along its north and south flanks ; but there is the strongest reason to believe that they do. If then we conceive the rocks to have run continuously at the same elevation round the head of the valley, and at the same time imagine the sea to have covered them as explained before, we have here precisely the circumstances which would produce all the phenomena we now behold. A bay or basin would thus be formed entirely sheltered from currents, and into which large quantities of the floating ice-islands would be driven by the winds ; and thus would be produced that irregular, rolling and deeply indented surface which we find prevailing from the eastern limits of Hamilton to Copetown. A succession of ridges of sand and gravel, no less than seven in number, in some places more, and in others less distinctly marked, have been traced for great distances along the north shore of Lake Ontario, and as far east as the Montreal Mountain and the slopes of the White Mountains in Vermont ; each preserving, as far as the Lake Ontario region is concerned, a uniform level at their bases, and all nearly parallel to each other and to the present beach of the Lake; but the lowest of these is one hundred and ten feet above the Lake at its base, and hence there is no reason to believe that the Heights form any portion of an ancient sea beach, as the others unquestionably are.* It is asserted by Lyell, on what seems to be uncontrovertible grounds, that these beaches indicate the succession of levels of the sea as the country underwent a gradual and intermittent upward movement after the deposition of the boulder or drift formation, which was the last great change previous to the present era in the earth's history.

I may remark here that the deep notch or indentation formed by the Niagara river at the whirlpool on the Canadian side, is bounded by a formation consisting exclusively of clay, cemented gravel and sand, with boulders both of granitic and limestone origin, precisely similar to the formation at Burlington Heights ; and that there is an obvious connection between this break in the older strata and the opening in the escarpment at St. David's, indicating that here a deep

* In the year 1852 in excavating through the Burlington Heights for the Great Western Railway, a gigantic tusk of a Mammoth or *Elephas Primiginius* was exhumed, having been buried in the solid conglomerate at the depth of forty feet below the surface ; and in the same cutting, the horn of a Wapiti or Canadian Stag was brought to light. This latter species is not yet quite, although rapidly becoming, extinct on this continent ; and the occurrence of its remains, associated with those of a species which has been extinct previous to the historic period, forms an interesting link between the past and present geological epochs.

valley had originally existed, which, during the glacial period, was filled up with the materials peculiar to it.

The average depth of the clay over the area comprised between the foot of the slope of the mountain and the lake shore seems to be about twelve feet; but at the artesian well at St. Catherines it is forty feet thick. There is a remarkable break in the continuity of the red marl of the Silurian formation, commencing at the eastern limits of Hamilton and terminating at the west side of the old canal; the intervening space being filled to an unknown depth with laminated clay and sand. May not this be accounted for by the abrasion and grinding down of the older soft marl, produced by the agitation of the icebergs which I have supposed to be congregated and imprisoned in this locality? The clay has been pierced to a depth of from sixty to seventy feet at the passenger station of the Great Western Railway without passing through it.

Succession of Changes.—I shall now in conclusion give a brief general retrospect of the probable succession of events which have produced the geographical and physical configuration of the region under notice.

The first event to which we must recur is the successive deposition, at a time vastly and immeasurably remote, of the stratified rocks shewn in these sections. I have said that they belong to the oldest fossiliferous rocks, and probably they contain the records of the first of living forms. That they are of marine origin is indisputable from the sea weeds and deep sea shells which they contain, but no trace of fishes, of vertebrated animals or of terrestrial vegetation can be discovered in them, and it seems to have been for many ages a creation of molluscs, corals and crustaceans. These rocks remained nearly undisturbed and horizontal from the era of their formation to a comparatively modern period, during which interval the whole of the geological formations subsequent to the Silurian system were deposited in different parts of the globe; and the vast succession of species of animals and plants whose histories we find written in these rocks have flourished and perished and been slowly entombed. During this interval also, and while the rocks in question still remained submerged in the ocean, they were denuded by currents, that is, portions were worn off and transported away, so as to form irregularities of surface, such as the basins of our great lakes, and

such valleys as those of St. Davids and the Welland Canal. They at length emerged slowly, and portions of their edges were removed by the action of waves and currents by which cliffs were formed at successive heights, such as those I have already adverted to around Flamboro' Heights. After this event another submergence under the sea occurred, and was followed by the glacial period, which it is to be remarked was of comparatively modern date. As soon as the table land between Lakes Erie and Ontario emerged, subsequently to the deposition of the drift and successive formation of the sea beaches, the River Niagara came into existence, the basin of Lake Ontario still forming part of the sea. The cataract would then be at Queenston, falling directly into the sea; and then would commence the retrograde course of the river, continuing uninterruptedly as already described, till the present time.

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